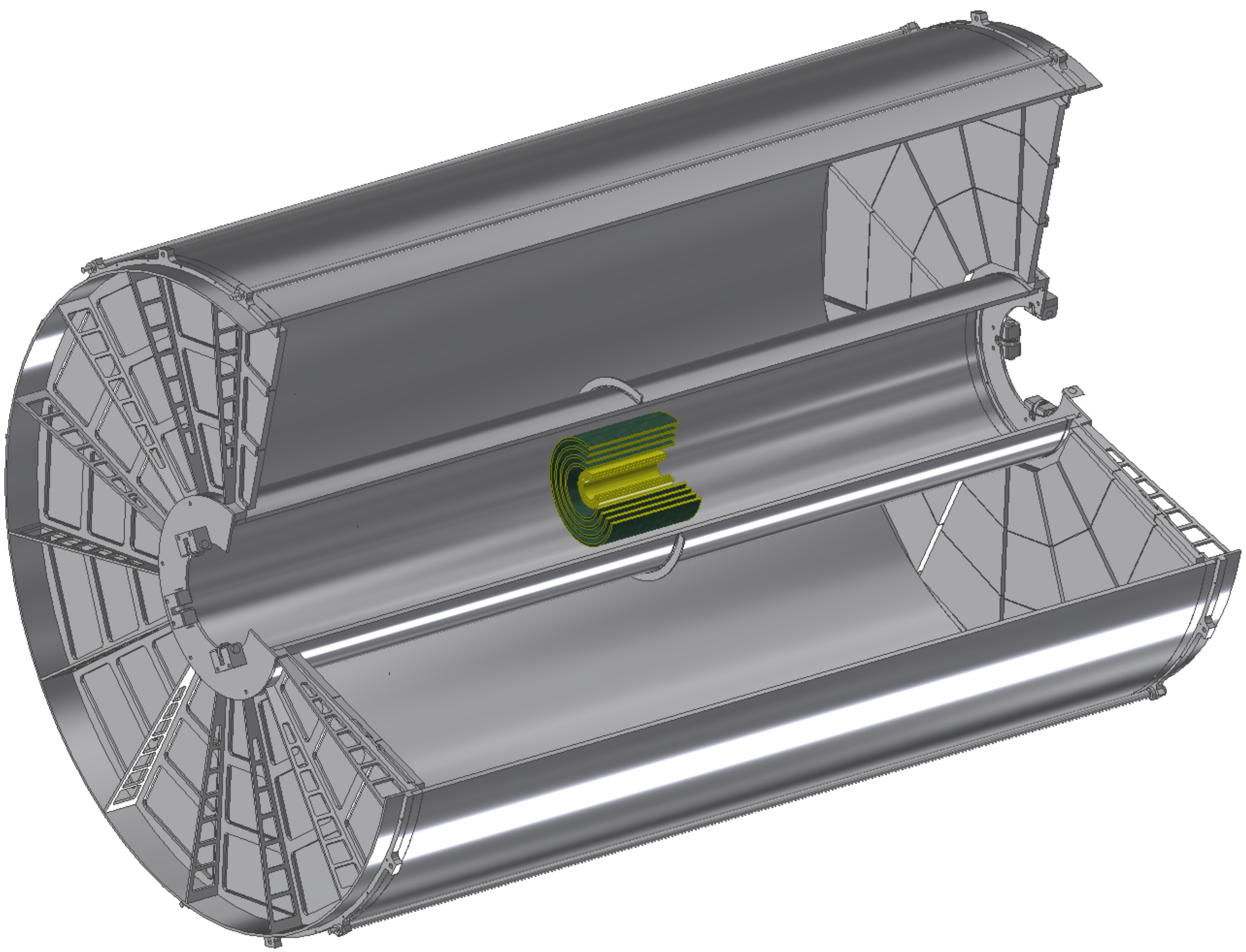
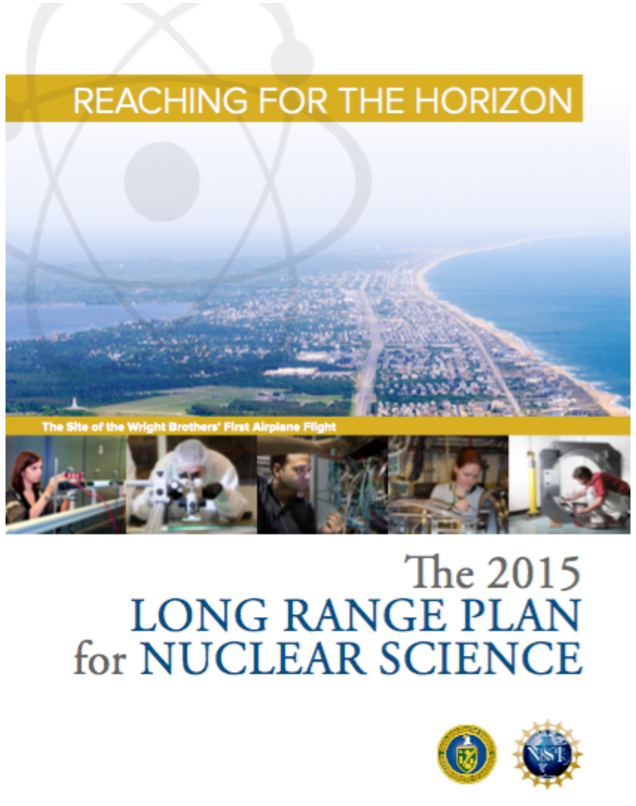
sPHENIX tracker

Science drivers, performance goals and technology choices

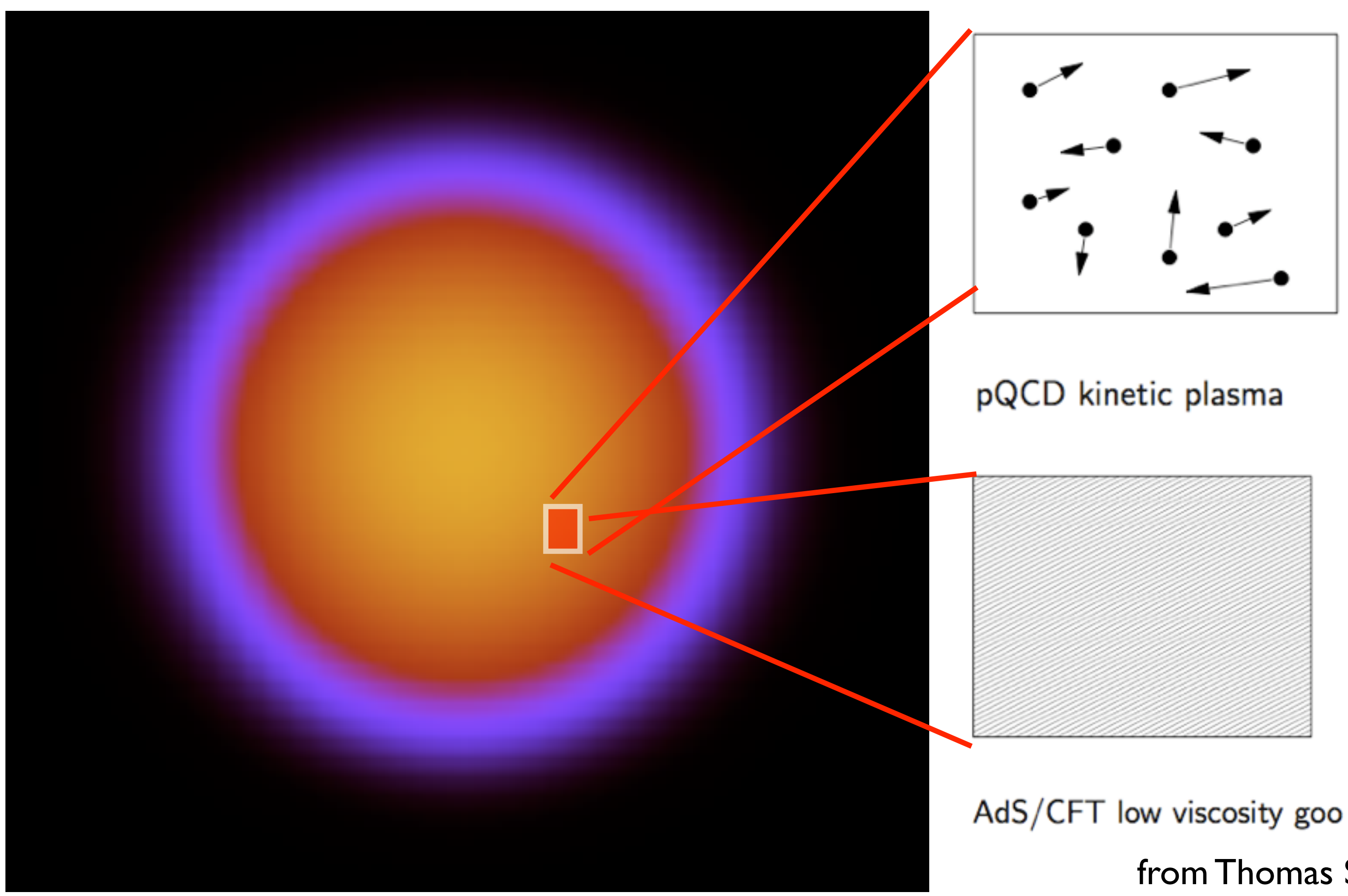


Gunther Roland (MIT), Dave Morrison (BNL)
for the sPHENIX collaboration

sPHENIX: Microscopic structure of QGP medium



There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**



from Thomas Schafer

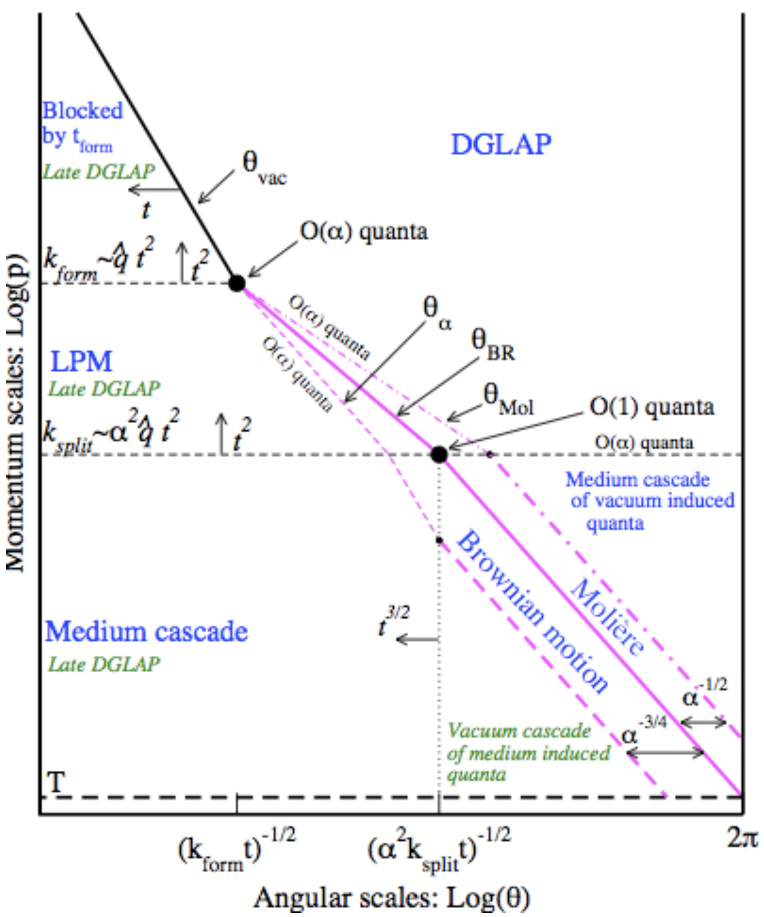
sQGP liquid $\overset{(?)}{\leftrightarrow}$ quasiparticles

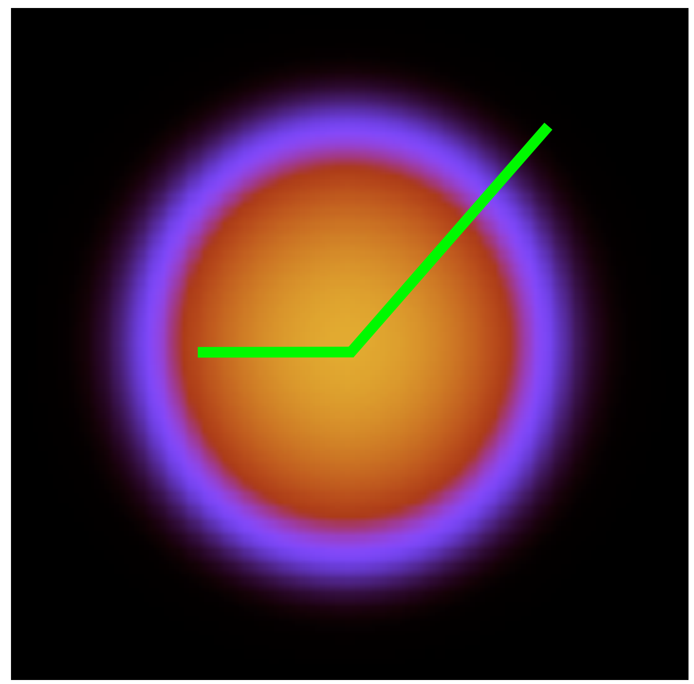
Unavoidable complexity due to strongly interacting nature of QGP probes

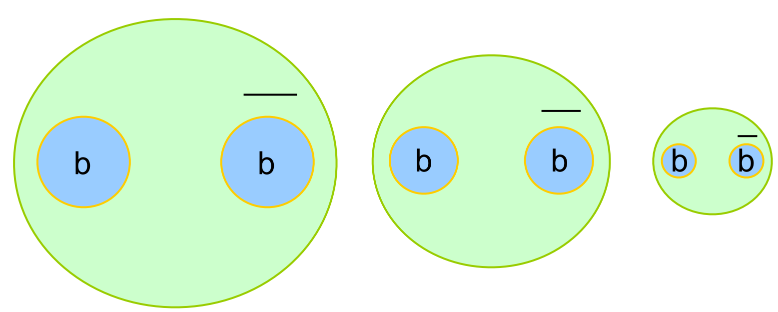
Multi-scale probes of QGP

Three key approaches to study
QGP structure at multiple scales

Jets and jet structure



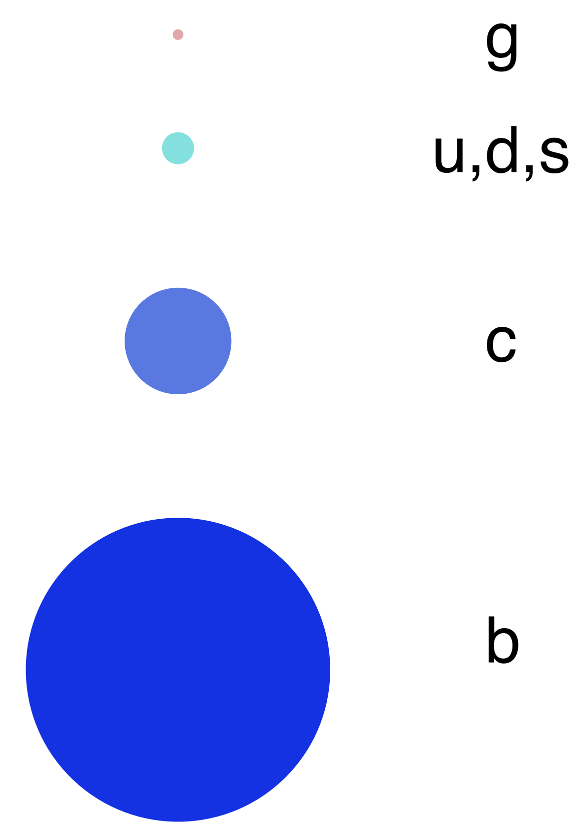




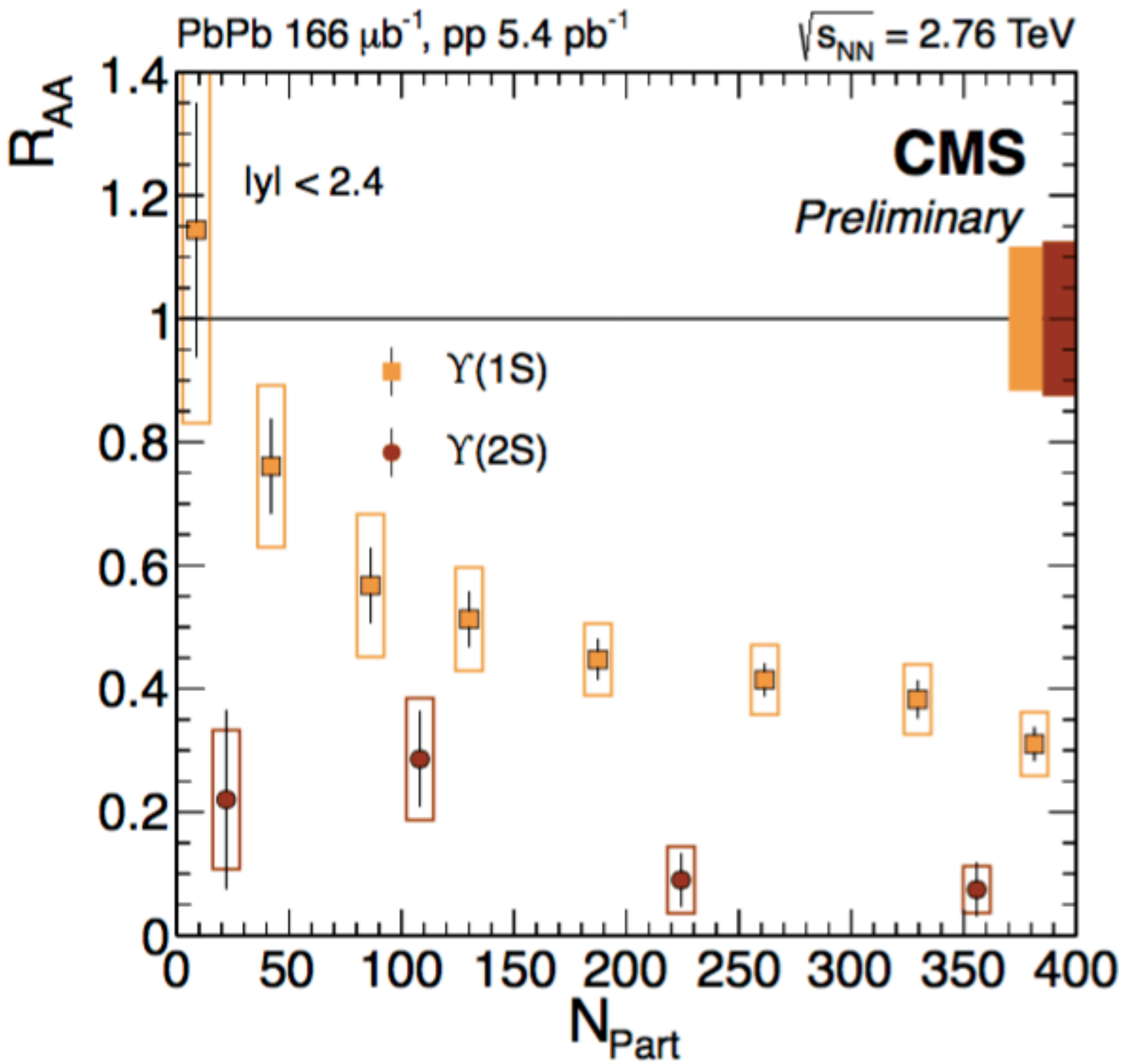
Υ(3s) Υ(2s) Υ(1s)

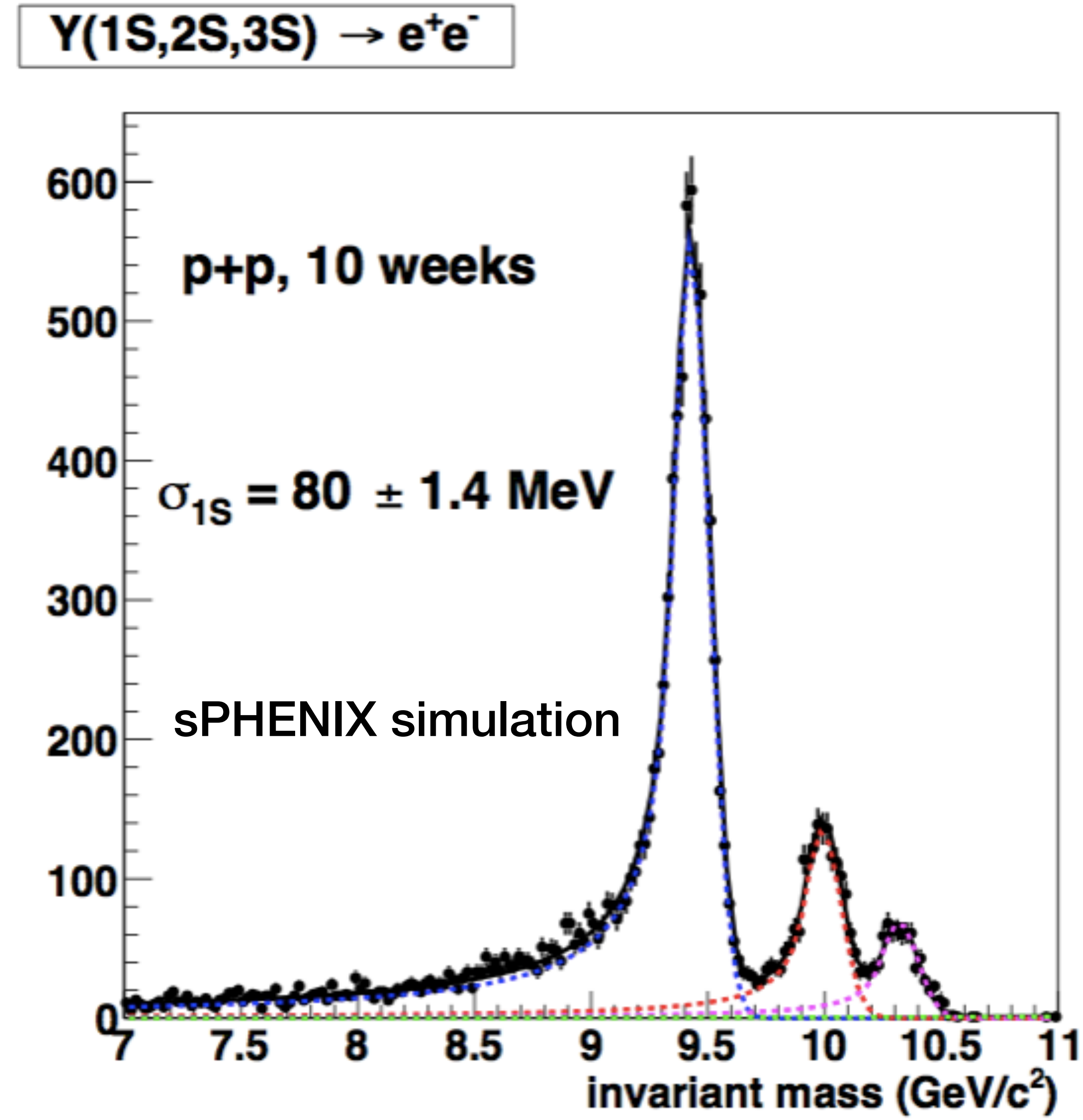
Upsilon spectroscopy

Heavy-flavor ID



Physics drives detector requirements: Υ(ns)





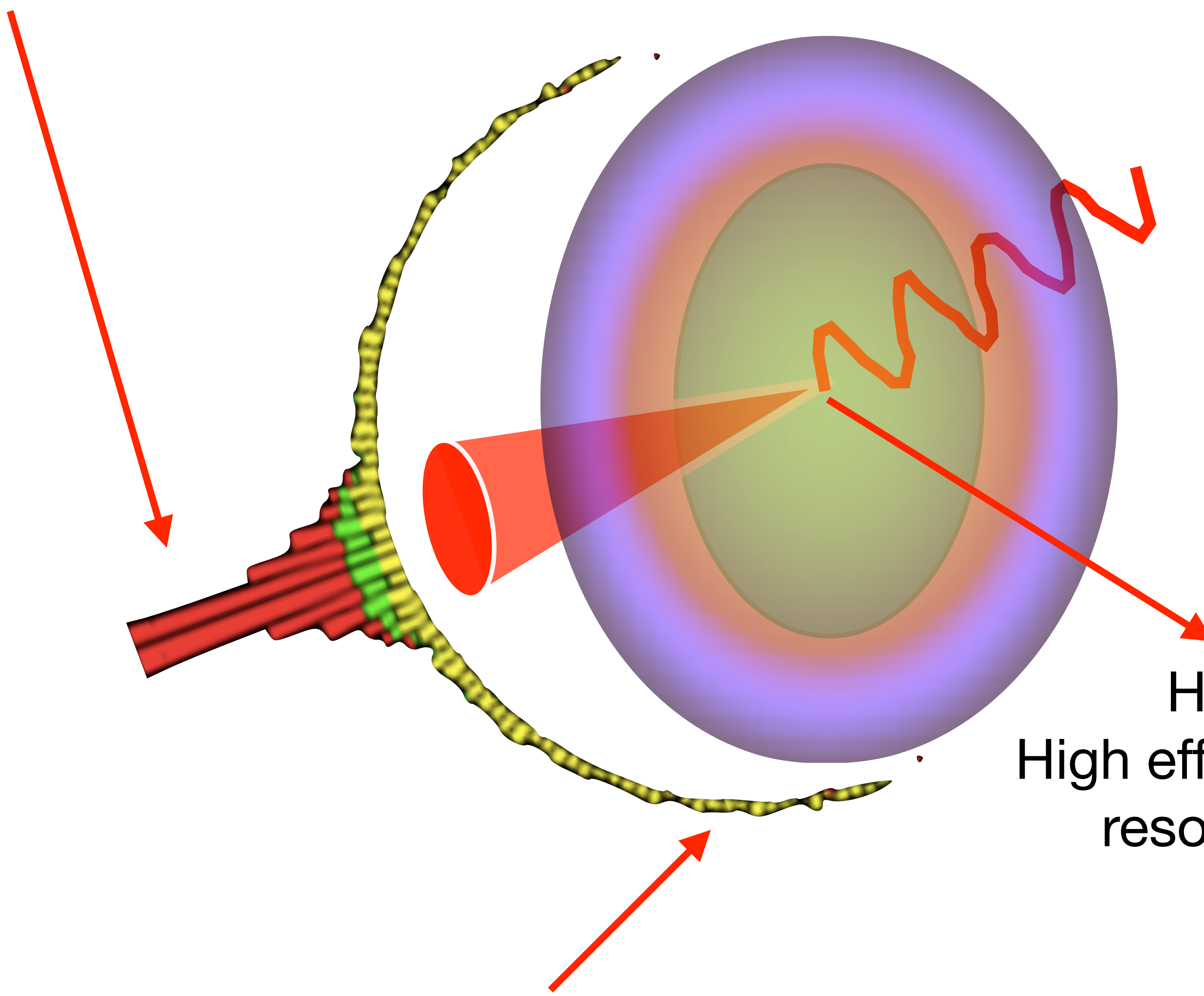
Rapid disappearance of Υ(2s), Υ(3s) in peripheral events is puzzling ➜
Statistics, statistics, statistics…

Count every Υ delivered ➜
high rate, large acceptance

Make every Υ count ➜
excellent momentum resolution

Physics drives detector requirements: Jets and tracking

Jet fragmentation:
Low fake rate and good resolution at p_T ~ 40GeV



Heavy Flavor tagging:
High efficiency and excellent DCA resolution for p_T ~ few GeV

Jet-medium interaction:
Well understood efficiency down to p_T~0.2GeV

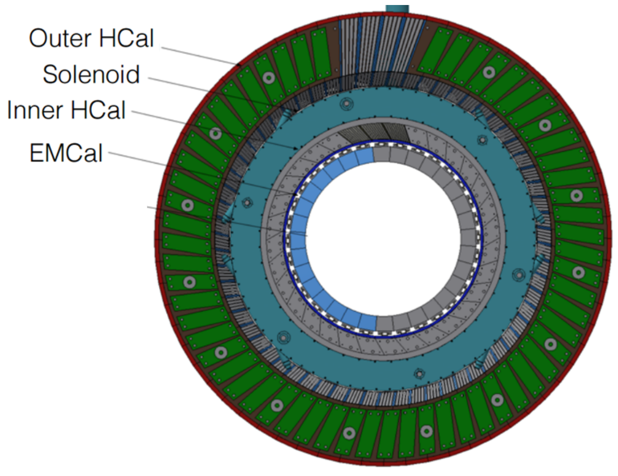
n.b. for 28 published jet papers from LHC HI, tracking is used in 24 and basis for main result in 10

Physics drives detector requirements

Physics goal	Detector requirement
High statistics for rare probes	Accept/sample full delivered luminosity (15kHz rate) Full azimuthal and large rapidity acceptance
Precision Upsilon spectroscopy	Hadron rejection > 99% with good $e^{+/-}$ acceptance Mass resolution 1% @ m_{Υ}
High jet efficiency and resolution	Full hadron and EM calorimetry Tracking from low to high pT
Control over parton mass	Precision vertexing for heavy flavor ID DCA_{vtx} < 70μm
Control over initial parton p_T	Large acceptance, high resolution photon ID
Full characterization of jet final state	High efficiency tracking for $0.2 < p_T < 40$GeV Uniform, constant tracking efficiency

Tracker concept

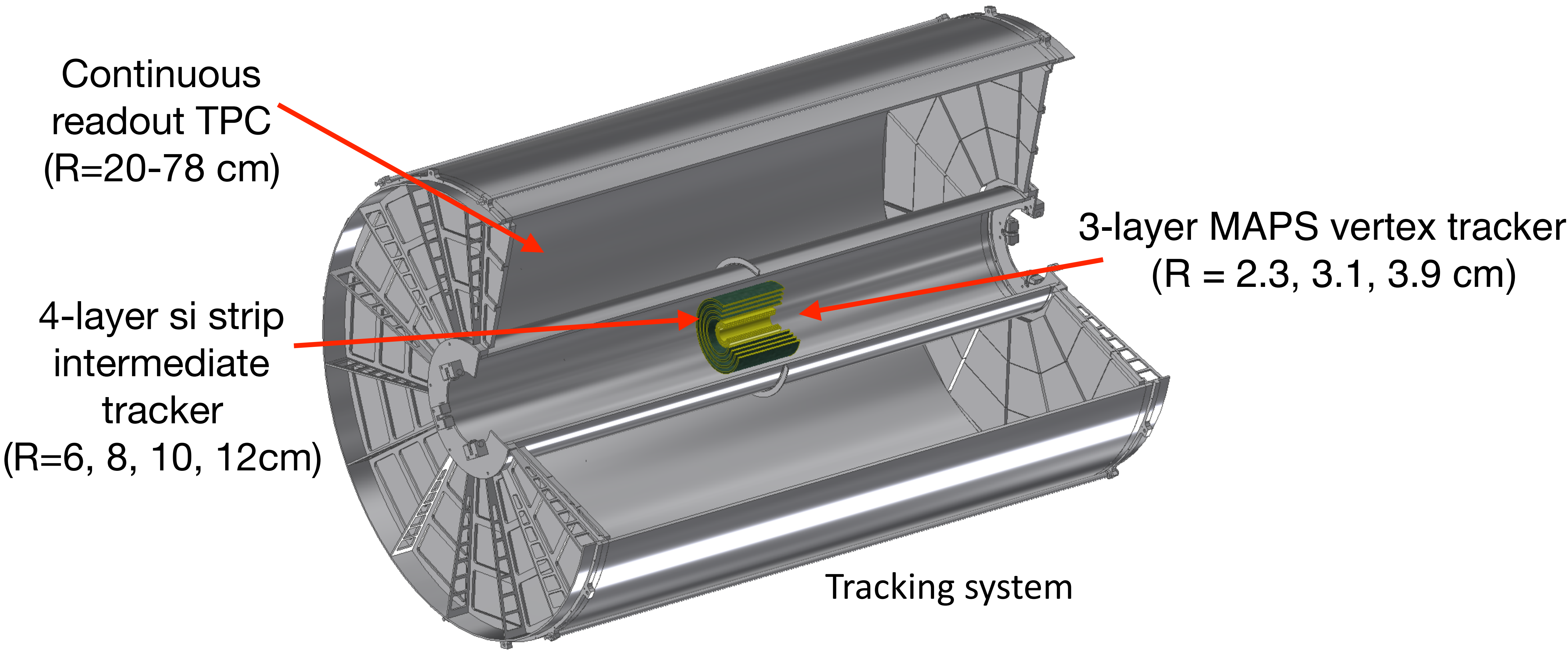
Calorimeter system



Track reconstruction over 2π, $|\eta| \sim 1$, $0.2\text{GeV} < p_T < 40\text{GeV}$

Outer radius constrained by EMCal geometry: R_{outer}<78cm
Inner radius constrained by beam pipe: R_{inner}>2.1cm

Three detector subsystems to provide primary+secondary vertex, pattern recognition, momentum resolution:



Tracking system

TPC design considerations

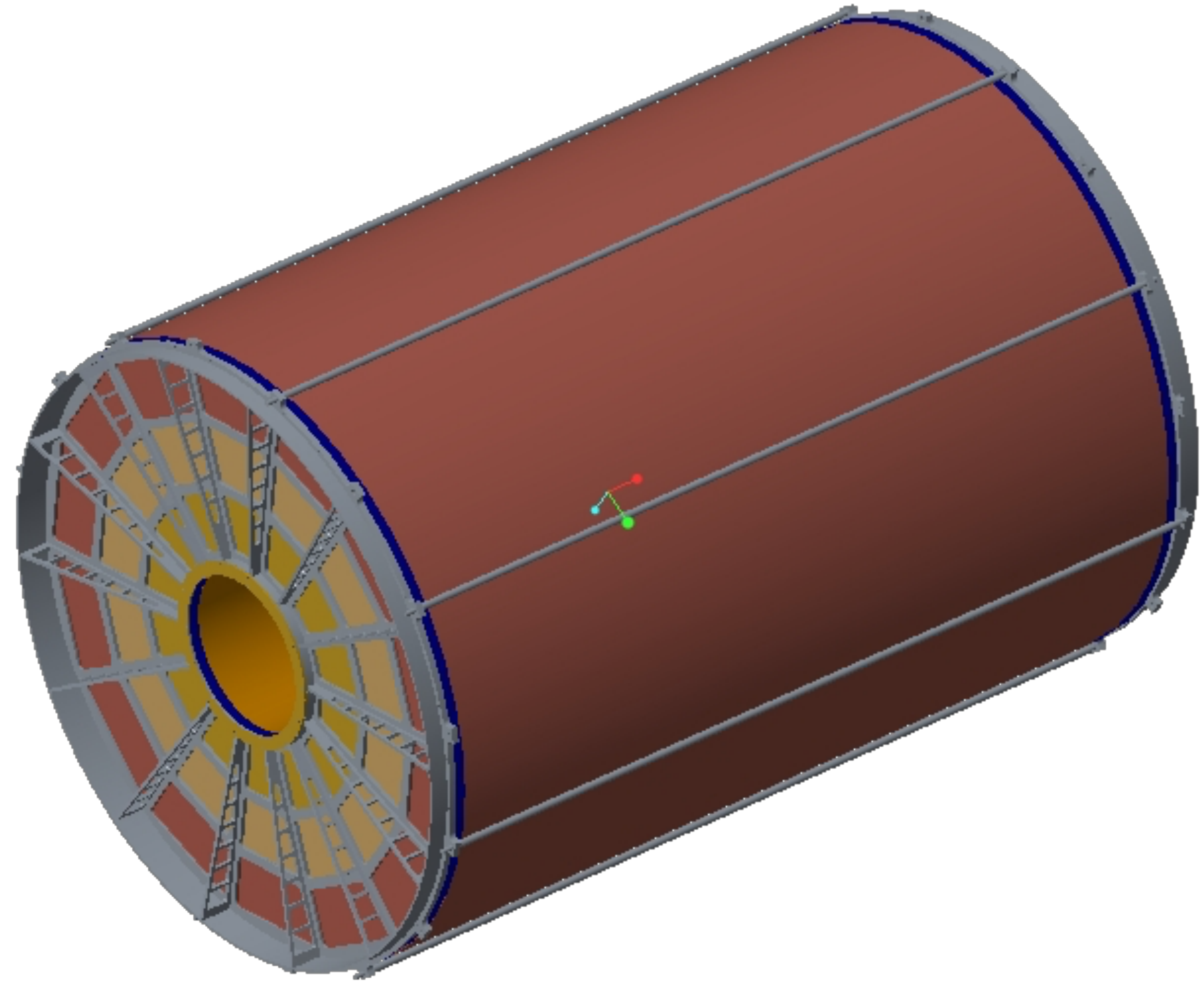
Key subsystem for pattern recognition and momentum determination

Track reconstruction over 2π, $|\eta| \sim 1$ and $0.2\text{GeV} < p_T < 40\text{GeV}$

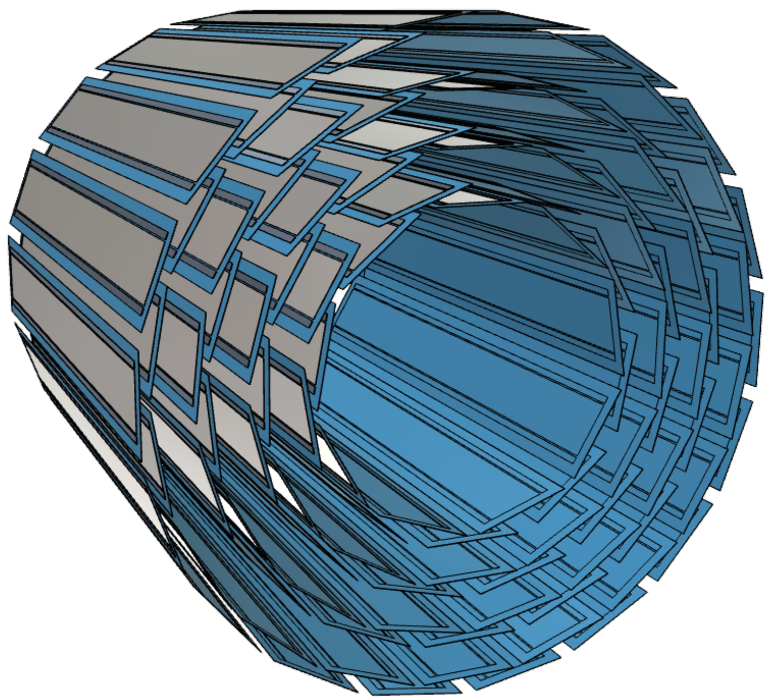
Readout at full collision rate (>15kHz) → Continuous (non-gated) readout

Υ mass resolution ~1% → effective hit resolution ~250μm

Uniform, time-invariant efficiency + resolution → control static and time dependent distortions



Intermediate tracker design considerations



Total Number of Ladders=108

Total 10 x 2 = 20 cells/ladder

Provide **essential** redundancy for pattern recognition, pile-up handling, DCA determination, MAPS →TPC matching and TPC static and time-dependent calibration

Stand-alone silicon tracking (MAPS + INTT) provides control over systematic uncertainties essential for physics goals (e.g. extremely rare high p_T tracks and very low signal/background jet-track correlations)

Must minimize material budget and technical risk

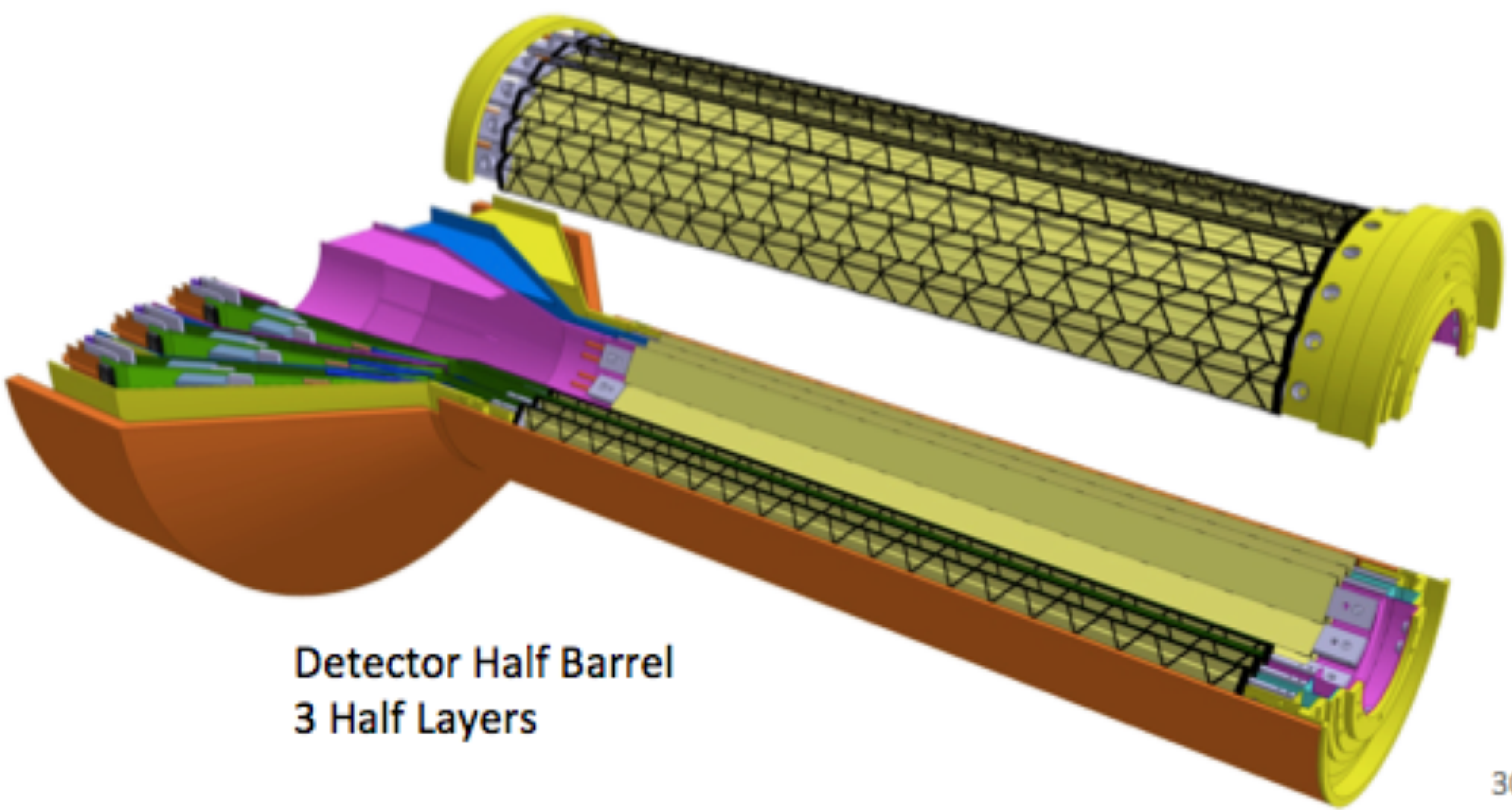
MAPS vertex tracker design considerations

MAPS vertex tracker enables heavy-flavor program

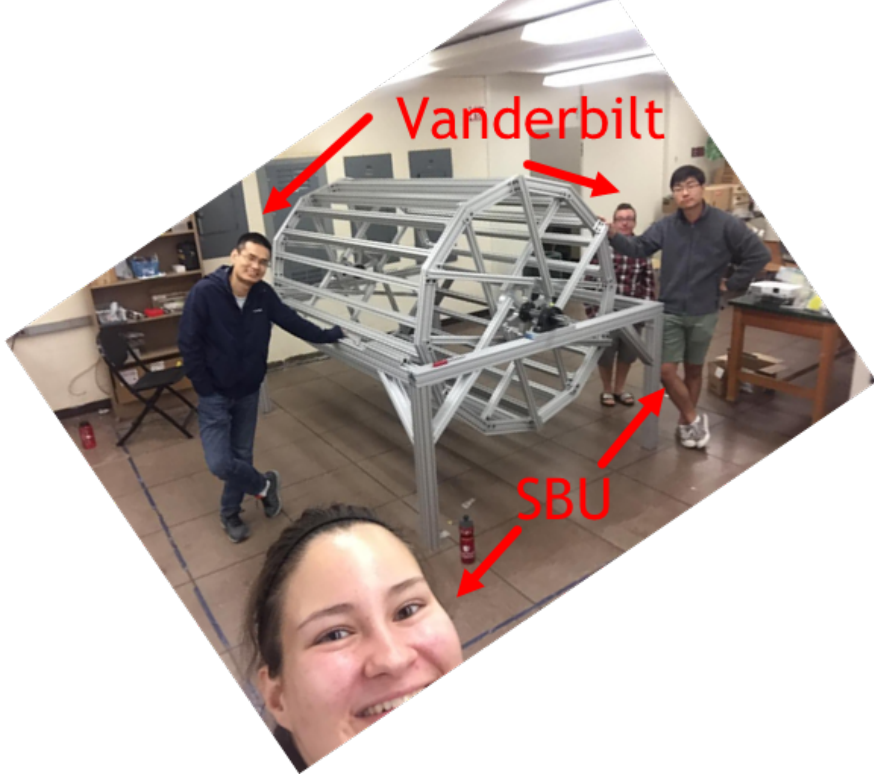
Maximize spatial resolution with minimal material budget to achieve DCA resolution $dca_{xy} < 70\ \mu m$

Readout at full collision rate (>15kHz) over $|z_{vtx}| \sim 10cm$

Requirements nearly identical to ALICE ITS upgrade → Copy ALICE ITS IB stave design



Status and challenges

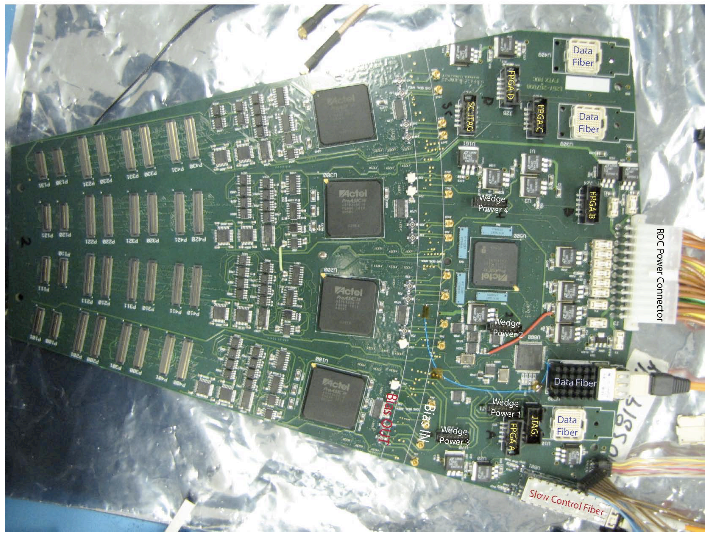


TPC

- BNL LDRD support
- v1 prototype Field Cage (full sized) under construction
- Work on mitigation of IBF distortion and other time-dependent calibrations
- E-field uniformity through precision in-situ measurements
- Collaboration with STAR experts on readout (data rate)

INTT

- Strong RIKEN/RBRC support
- Hamamatsu single sided si strip sensors
- Re-use of PHENIX FVTX components
- Sensor thinning, readout development, schedule



MAPS

- Strong LANL support via LDRD
- sPHENIX MAPS “consortium” being formed
- Acquired MAPS prototype board
- Coordination with ALICE/CERN production schedule
- sPHENIX Integration (mechanical/readout)

Summary

sPHENIX will be a state-of-the-art jet and upsilon detector at RHIC, designed to fulfill the Hot QCD mission outlined in the 2015 NP LRP

Large acceptance, high resolution, high purity, full rate tracking is key to every aspect of the science program:

- Upsilons, jets and open heavy-flavor

Combination of 3 subsystems to achieve performance within budget and schedule constraints:

- MAPS vertex tracker (copy of ALICE IB)
- INTT silicon strip (PHENIX FVTX experience)
- TPC w/ continuous readout (ILC and ALICE/STAR experience, front-end readout)